ACCELERATOR COMPONENT VIBRATION STUDIES AND TOOLS

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Abstract

Mechanical design of the ILC (International Linear Collider) cryomodules is presently under development [1]. The design under consideration is a further evolution of the cryomodules built in several units, and with several revisions, for the linac of the TESLA project [2]. Nevertheless, except for the proposed new location of the quadrupole package at the center of the module, the main features and the layout of the components inside the main cryogenic vessel, with the Helium gas return pipe (GRP) as the main structural element, are preserved [1]. Therefore, a detailed study of the mechanical behavior of the TESLA modules is useful to provide a reliable input for the ILC cryomodule design. In this work, we have focused our investigation on the support structure of the quadrupole, as designed for TESLA Type II cryomodules. We have measured the displacement power spectral density (PSD) at different positions and integrated the spectra to obtain root mean square (rms) displacement for these positions. We have also calculated the mechanical transfer function from the vacuum vessel to the quadrupole package and have checked for internal resonances [3]. The measurements, performed at room temperature with inertial sensors, confirm reliability of the TESLA cryomodule design, in terms of vibrational stability, with the quadrupole, supported by the GRP, located at the end of the cryomodule.

INTRODUCTION

The cryomodule under this investigation, is about 12 m long, contains eight 9-cell superconducting Nb cavities, a cold cavity type beam position monitor and a superconducting magnet package at one end. Mechanically, the string of the cavities and the quadrupole package are supported by a 300 mm inner diameter Helium GRP.

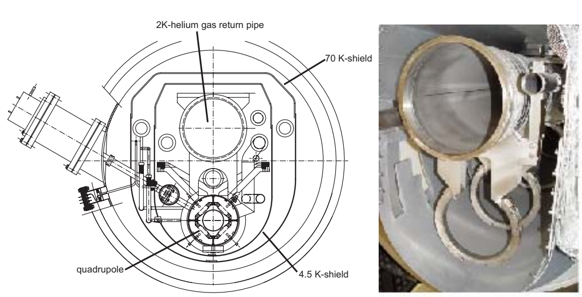

Fig.1: Cross-section of a Type II cryomodule (left) [2], quadrupole support structure (right).

The GRP is supported from above by three posts consisting of large diameter thermal insulating fiberglass pipes terminated by two shrink-fit stainless steel flanges. The posts are fastened to large flanges on the upper part of the vacuum vessel by adjustable suspension brackets for alignment purposes; the central post is fixed while the two laterals can slide, longitudinally, to compensate for the thermal differential shrinkage. The quadrupole package is connected to the GRP by two large and stiff ring brackets split in halves for easy mounting and alignment (see Fig.1, right).

TYPE II CRYOMODULE VIBRATIONS

Vibrational stability of the quadrupole package both in the vertical and the horizontal transverse directions to the beam pipe was investigated using the environmental noise (floor and facility) as a source of vibrations. In this experiment, two broadband triaxial seismometers Güralp and four single-axis geophones were used. Further details on the data acquisition system and analysis are presented elsewhere [3].

Fig.2: TESLA type II cryomodule setup in Hall 3 in DESY for vessel vs. ground measurement.

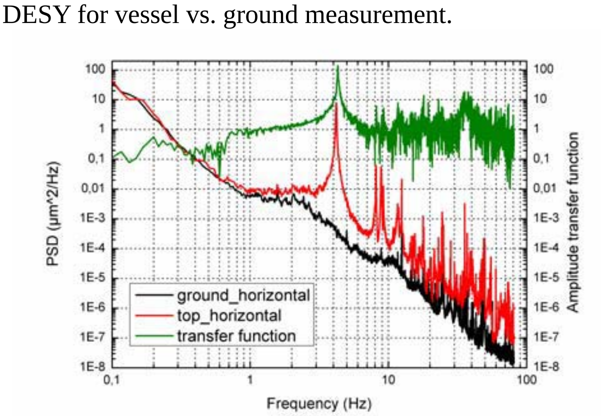

Fig.3: Comparison between the PSD spectra on the ground and on top of the module in horizontal transverse direction.

The end caps of the cryomodule were removed to get direct access to the quadrupole and to the GRP. The cryomodule was supported on four steel pads placed on two concrete slabs. For reference, motion of the main vessel was compared with the ground, by using two seismometers, one which was placed on top of the module close to the main flange of the vessel (see Fig. 2). Three large amplitude mechanical resonances, due to the motion of the vessel on the supports, appear at 4.3, 8.3 and 9 Hz. In the horizontal transverse axis (perpendicular to the beam line), the motion is dominated by the 4.3 Hz mode (Fig.3), while the modes at 8.3 and 9 Hz have the largest amplitude along the horizontal longitudinal direction [3]. These three modes are not purely translational as shown by the strong coupling with the vertical direction (Fig.4). The coherence function [3], as shown in Fig.5, is very low at the corresponding resonant frequencies. It implies that they are mainly excited by the horizontal floor motion.

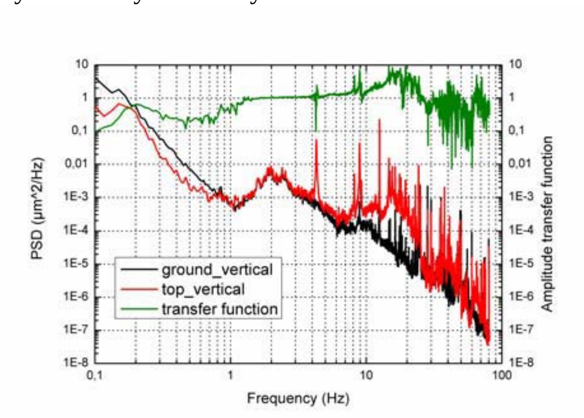

Fig.4: Vessel top to ground comparison in vertical direction.

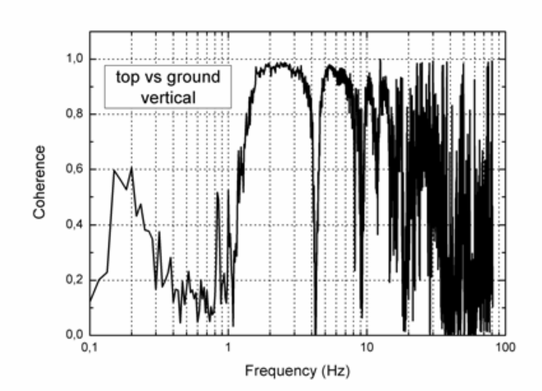

Fig.5: Coherence between the ground and on the top of the vessel, in vertical direction.

Helium Gas Return Pipe Stability

For the test of the rigidity of the vessel to GRP connection, one seismometer was placed on top of the vessel, and another one, inside the GRP, just above the quadrupole. Comparison between the measured spectra (see Fig.6 and Fig.7) shows a good agreement between the PSD spectra at these two positions in both directions.

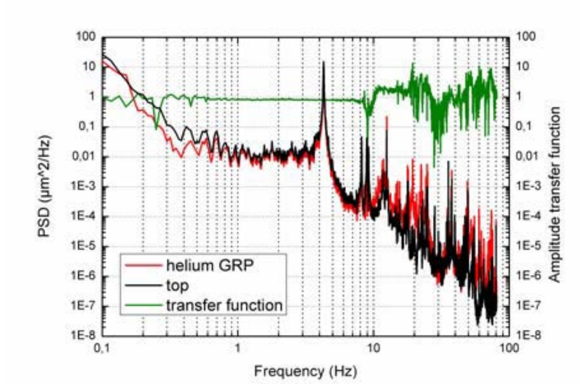

Fig.6: Vessel top to GRP comparison in transverse direction.

There is no evidence for mechanical resonances, in the explored frequency range, as shown by the calculated transfer functions (Fig. 6 & Fig. 7). The difference in the integrated rms amplitude is less than 30% at 1Hz in both axes (Fig.8).

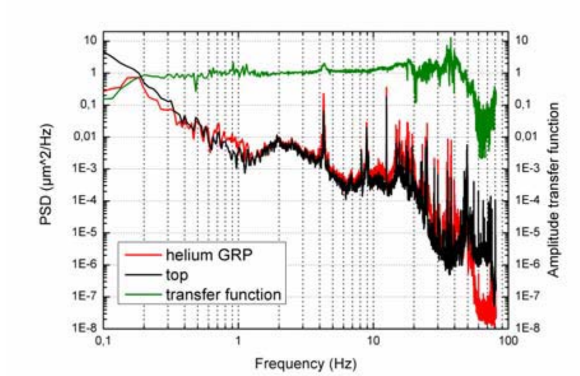

Fig.7: Vessel top to GRP comparison in vertical direction.

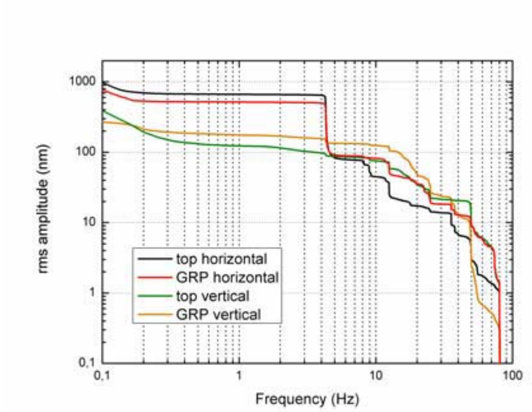

Fig.8: Vessel top to GRP rms amplitude comparison.

Quadrupole Stability

The stability of the quadrupole to GRP connection was studied using geophones because of the small space available on the quadrupole. In this measurement, the cryomodule was placed on its assembly stand, located near an electrical motor rotating at 24.5 Hz.

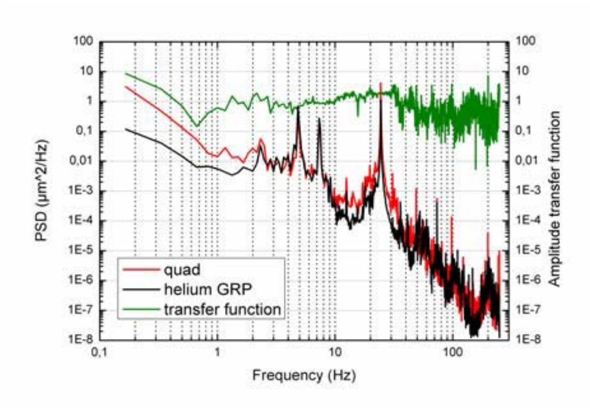

Fig.9: Quad to GRP comparison in transverse direction.

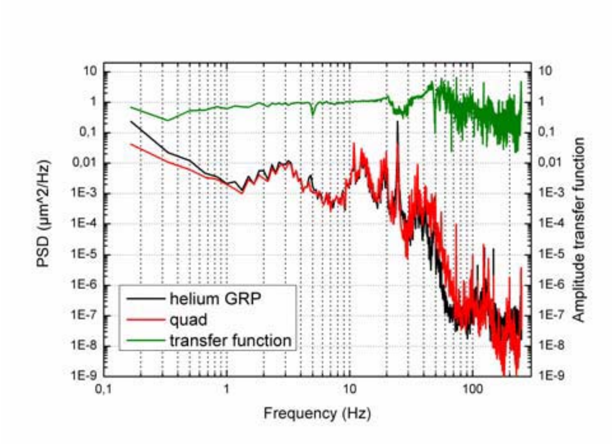

Fig.10: Quad to GRP comparison in vertical direction.

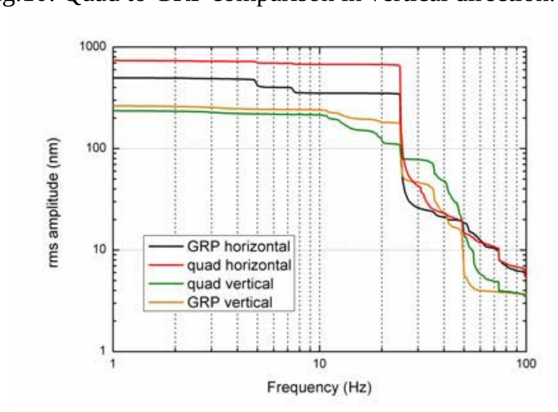

Fig.11: Quad to GRP rms amplitude comparison.

Even in this case, no evidence for mechanical resonances was found in the transfer function in both axes (Fig.9 and 10). In the integrated rms comparison (Fig.11), the large peak at 24.5 Hz masks a very good matching between the spectra, better than 20% (estimated by removing the peak from the integration).

Future Investigations

More investigation is necessary to evaluate possible excess quadrupole vibrations produced in cryogenic operation by the Helium gas flow in the GRP and by the pressure oscillations in the liquid He feed lines. The only available data from the TTF (Tesla Test Facility), at DESY, are inconclusive for the ILC cryomodule design because of the much lower dynamic heat load and lack of sensitivity of the piezo charge mode accelerometers used below 10 Hz [3]. There are plans to measure the relative motion between the quadrupole and the main vessel, along horizontal and vertical directions, interferometrically, by using two small retroreflectors attached to the cold mass as targets. For this purpose, next XFEL Module 8 and 9 will be provided with suitable viewports and two lines of sight, towards the quadrupole, will be opened through the two thermal shields. In order to discriminate the quadrupole vibrations from the cryomodule absolute motion, a witness geophone will be used at the reference mirror location.

CONCLUSIONS

Vibration spectra measured at different points in/on the investigated type II cryomodule are dominated by the noise sources in the facility and by large amplitude common modes due to the supports of the main vessel. A good agreement have been found in the integrated rms values at 1 Hz at different measured points, better than 30% between vessel top and GRP and better than 20% between GRP and the quadrupole. Beyond 10 Hz, the measured difference in the integrated rms is systematically larger (up to 70%) both at the GRP with respect to the vessel top and at the quadrupole with respect to the GRP. This effect requires further investigation. Nevertheless, point to point measurements of the transfer function shows no evidence for mechanical resonances of the quadrupole support structure, proving reliability of the design

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REFERENCES

[1] ILC Baseline Configuration Document (BCD), http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home

[2] TESLA Design Report (2001).

[3] R. Amirikas, A. Bertolini, W. Bialowons, H. Brück, "Quadrupole Vibration Measurements of a TESLA Type II Cryomodule", EUROTeV Report 2006-036.